AS Unit BY2: Biodiversity and Physiology of Body Systems

Name:	Date:

Topic 2.3 Transport (Animal) – Page 2

		Completed
1.	Watch the animation and recap the structure of the heart and how blood flows through the heart. • Appreciate that the heart is 2 pumps side by side • Understand why the thickness of the walls varies between right and left side and between the ventricles and the atria. • Appreciate the role of the valves between the atria and ventricles and in the arteries that leave the heart.	
2.	Read about the flow of blood in the cardiac cycle p2 and watch the animation. Complete the questions on p3.	
3.	Look at the graphs of p4 and look at the pressure changes during the cardiac cycle. • You should be able to understand why the pressure is changing in the different chambers. • You should also appreciate why the valves are forced open and closed.	
4.	Complete the questions on p5-7	
5.	Look at the animations explaining the electrical activity over the heart. Complete the questions about the spread of electrical activity and an ECG p8-10.	
6.	Putting it ALL together. You are tasked with the creation to create a flipbook about the cardiac cycle. You need to annotate the book with descriptions of pressure volume changes and also include the electrical activity of the heart.	

Cardiac Cycle

The heart is in effect 2 pumps lying side by side. They both work together sending blood around the pulmonary or systemic circuit.

The sequence of events in a single heartbeat is known as the cardiac cycle. The cycle involves systole, or contraction and diastole, or relaxation.

The cycle has four overlapping events:

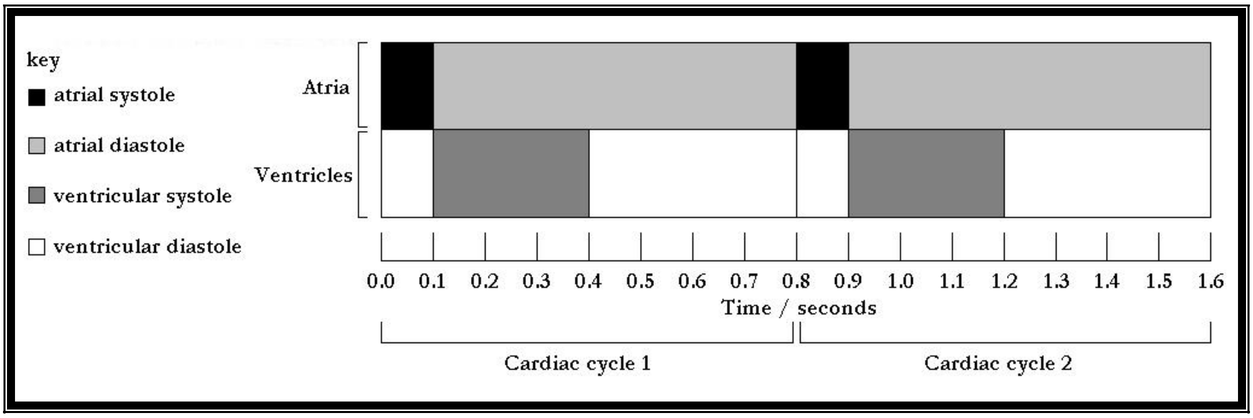
- **Atrial Systole**. Some of the blood that enters the atria flows immediately into the ventricles the rest is forced through by the atria contracting. Both atria contract forcing the blood into the ventricles, this stage lasts about 0.1 seconds.

- **Ventricular systole**. Both ventricles contract, forcing blood through the semi-lunar valves into either the pulmonary artery to the lungs and or the aorta to the body. This takes about 0.3 seconds. At the same time that the semi-lunar valves are forced open the atrio-ventricular valves are forced shut. The forced closing of the AV valves gives the characteristic ‘lub’ of the ‘lub-dup’ heart sound. Pressure in the arteries increases as blood is forced into them.

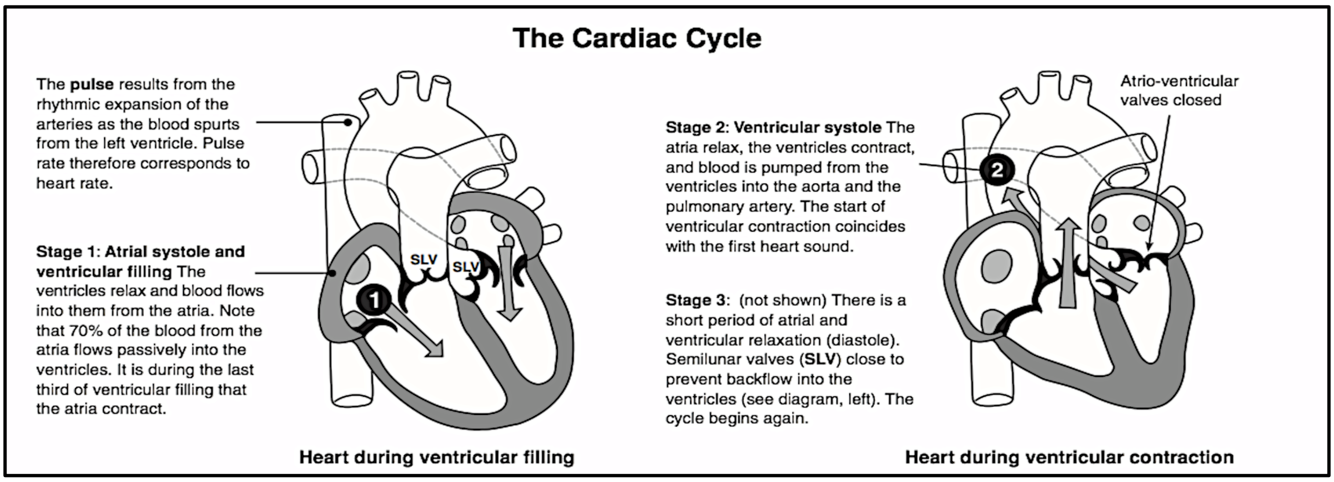
- **Atrial diastole**. The atria relax and this occurs at the same time that the ventricles are contracted. Blood enters the large veins coming from the body and lungs. This takes about 0.7 seconds.

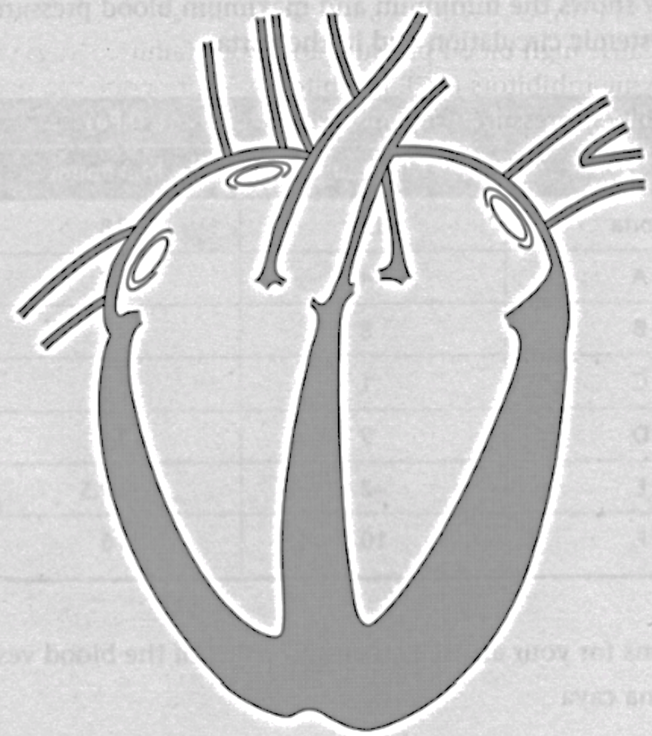
- **Ventricular diastole**. The ventricles relax, and become ready to fill with blood from the atria as the next cycle begins. The flow of blood into the ventricles causes the semi-lunar valves to shut, causing the ‘dup’ heart sound. This takes about 0.5 seconds.

On average the cardiac cycle lasts about 0.8 seconds.



(Note, valves are simply flaps of tissue, they do not open and shut by themselves, they are either forced open or closed by blood being pushed against them).





① The diagram above shows the heart during diastole (relaxation) but without any of the valves drawn. Complete the diagram to show clearly the main features of the cardiac cycle during ventricular systole (contraction). You should include:

- the position of all the valves, showing clearly whether they are open or closed
- arrows showing the blood flow through the heart and major vessels
- the names of all the major blood vessels and the chambers of the heart
- the size of the ventricles in comparison with their size during diastole – draw a line to show the expected outline of the ventricle.

② The pressure exerted by the left ventricle is higher than that exerted by the right ventricle.

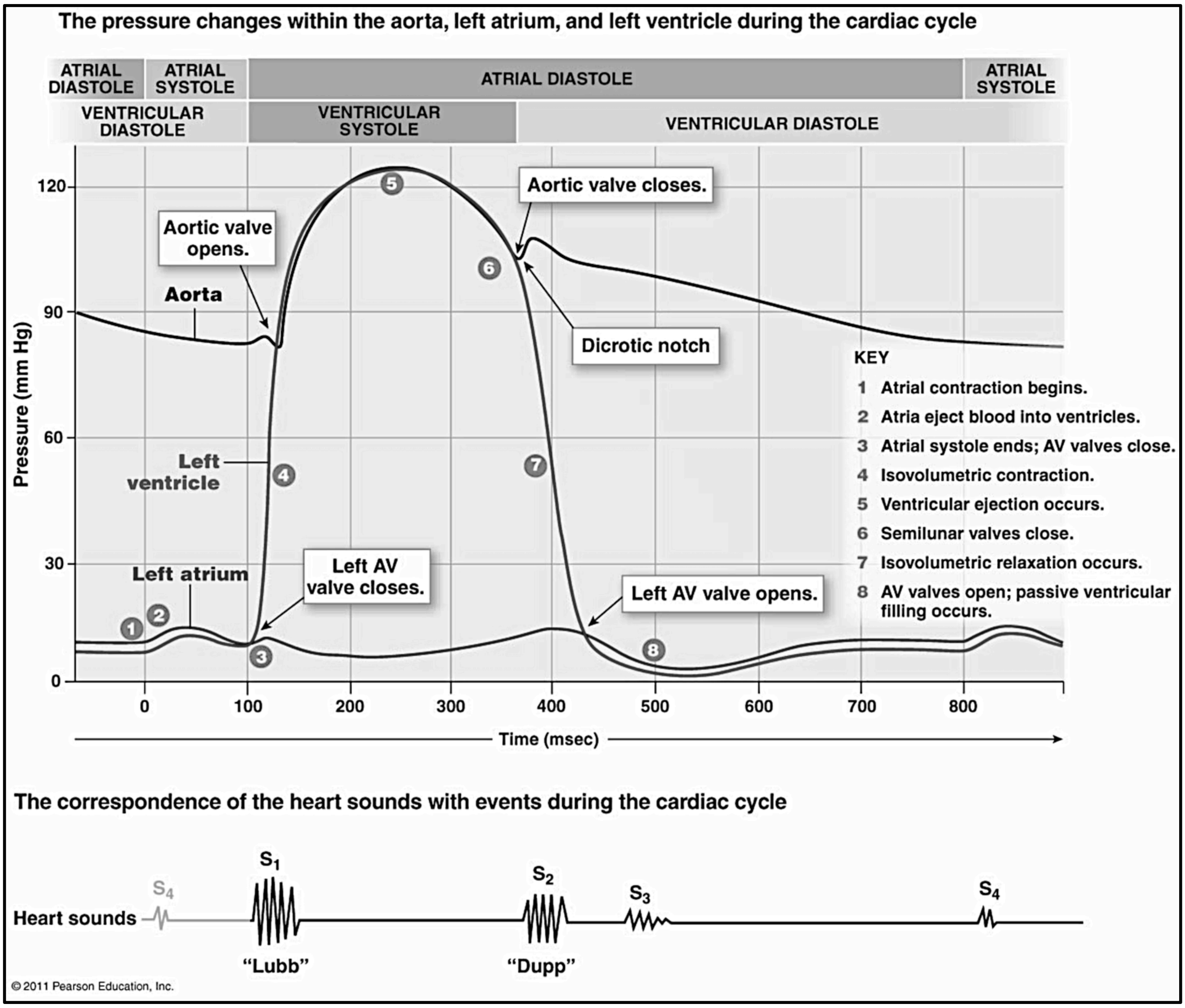
a Which feature of the heart's structure allows a different pressure to be exerted by the two sides of the heart?

....

b Explain why the heart has to exert more pressure on the blood in the left ventricle than on that in the right ventricle.

....

....


The pressure changes within the aorta, left atrium, and left ventricle during the cardiac cycle
ATRIAL DIASTOLE
ATRIAL SYSTOLE
ATRIAL DIASTOLE
ATRIAL SYSTOLE
VENTRICULAR DIASTOLE
VENTRICULAR SYSTOLE
VENTRICULAR DIASTOLE
Pressure (mm Hg)
Aortic valve opens.
Aortic valve closes.
Aorta
Dicrotic notch
Left ventricle
Left atrium
Left AV valve closes.
Left AV valve opens.
KEY
1 Atrial contraction begins.
2 Atria eject blood into ventricles.
3 Atrial systole ends; AV valves close.
4 Isovolumetric contraction.
5 Ventricular ejection occurs.
6 Semilunar valves close.
7 Isovolumetric relaxation occurs.
8 AV valves open; passive ventricular filling occurs.
Time (msec)
The correspondence of the heart sounds with events during the cardiac cycle
Heart sounds
S4
S1
S2
S3
S4
"Lubb"
"Dupp"
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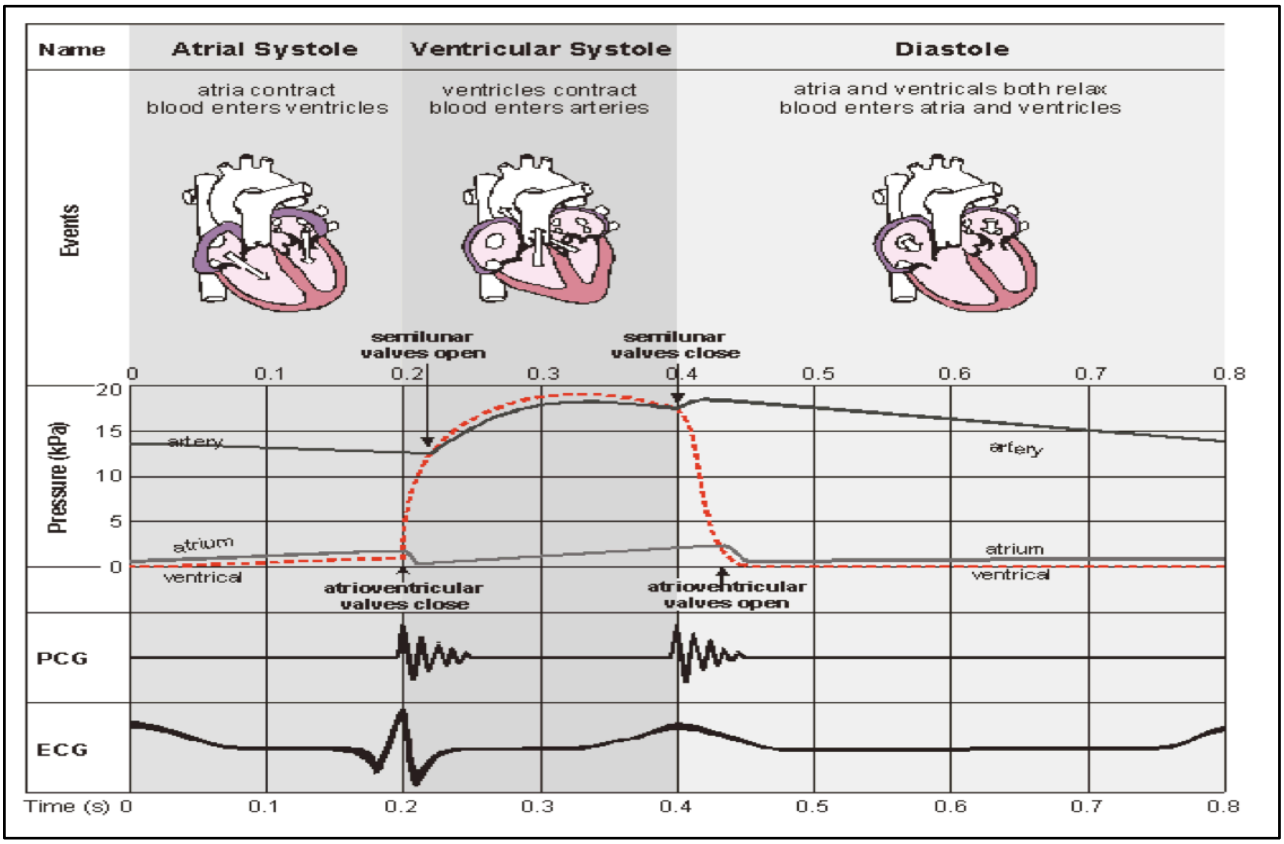

Name
Atrial Systole
Ventricular Systole
Diastole
Events
atria contract blood enters ventricles
ventricles contract blood enters arteries
atria and ventricals both relax blood enters atria and ventricles
semilunar valves open
semilunar valves close
Pressure (kPa)
artery
artery
atrium
atrium
ventrical
ventrical
atrioventricular valves close
atrioventricular valves open
PCG
ECG
Time (s)

Complete the following paragraph that describes what happens to bring about opening and closure of these valves:

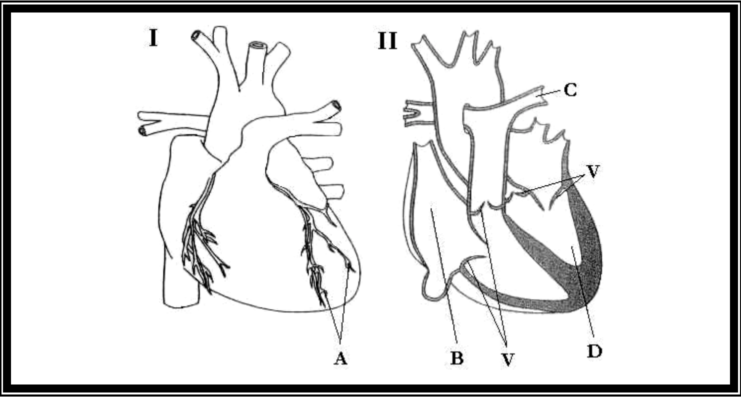
Opening Atrioventricular Valves:	Key Word
1. Ventricles relax and their walls	
2. Pressure in the ventricles drops below	
3. Atrioventricular valves	
4. Blood enters the heart and flows through the atria into the	
5. The pressure in the atria and ventricles slowly rises as they fill with	
6. The valves remain open while the atria	

Closing Atrioventricular Valves:	
7. Ventricles contract and the blood pressure in them	
8. The pressure in the ventricles rises above the pressure in the	
9. The blood pushes upwards and fills the valve	
10. This prevents the blood flowing back into the	

recoil	Ventricles	Pockets	open
Rises		atria	Atria
atria	Blood		contract

Questions:

1. Diagrams I and II shown on the right show the internal and external features respectively of the mammalian heart.



   a. Name structures A to D.

   A. ______________________________ B. ____________________________________

   C. ______________________________ D. ____________________________________

   b. Suggest the likely effects on the circulatory system of the following heart defects:

      i. A baby is born with a hole in the wall between the left and right chambers of the heart.

      ____

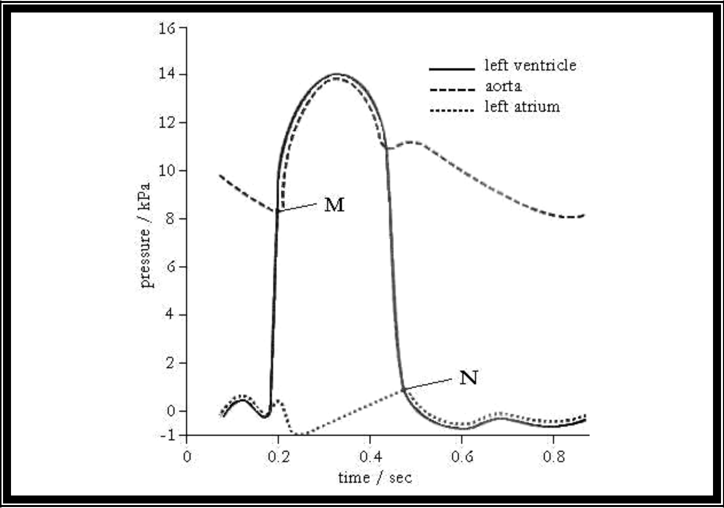
      ii. Valves (**V**) not working properly.

      ____

      ____

   c. Diagram shows the pressure changes in various parts of the circulatory system during one cardiac cycle

   At **M** and **N** the valves are either opening or closing.



   With reference to diagram III, explain what is happening at **M** and **N**.

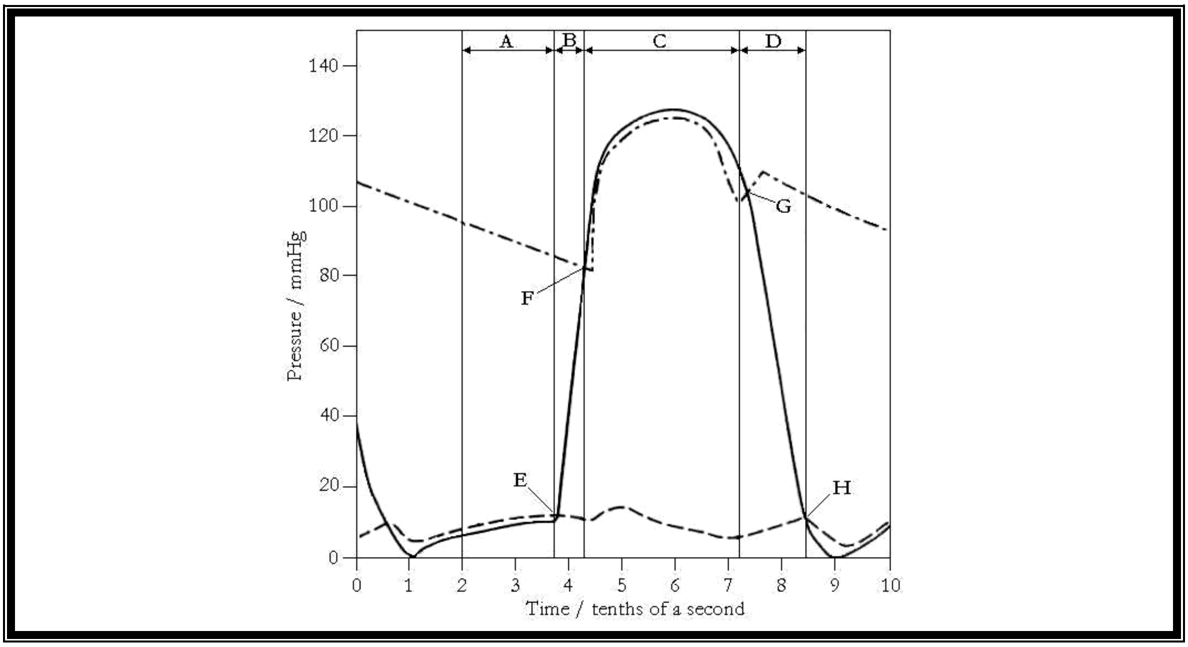
   ____

   ____

   d. Explain why the maximum pressure in the left atrium is lower than the maximum pressure in the left ventricle.

   ____

2. The graph below shows changes in pressure in the heart and aorta during the course of a heartbeat (cardiac cycle).



a. Pressure was recorded in three regions: left atrium, left ventricle and aorta. Indicate which line (continuous, broken or dot-and dash) you think represents each region and give a reason for your choice.

Continuous: ______________________________

Broken: ______________________________

Dot-and-dash: ______________________________

b. On the graph which one of the periods (labeled A-D) or points (E-H), identifies each of the following? The time when

i. The atrio-ventricular valve closes ______________

ii. The semi-lunar valve closes ______________

iii. The ventricle is filling with blood ______________

iv. The ventricle is emptying ______________

v. The volume of the ventricle is not changing ______________

c.

i. From the graph estimate the diastolic arterial pressure that would be measured in this subject in an artery where it branches from the aorta.

____

ii. The total period displayed in the graph is actually slightly more than the duration of a single heartbeat. Calculate the pulse rate in beats per minute for this subject.

____

Control of the Cardiac Cycle

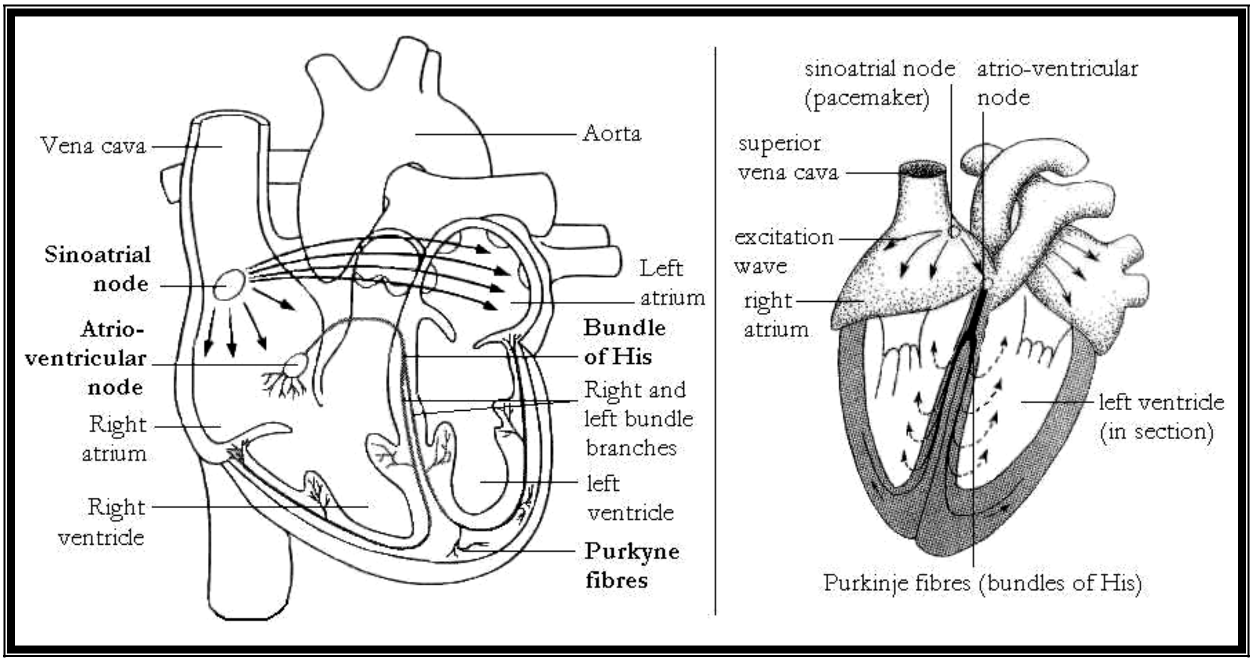
Cardiac muscle will continue to beat rhythmically even after it has been surgically removed from the body provided that it is maintained in a favourable medium. This shows us that the origin of the heartbeat is actually within the heart muscle itself rather than from an external nerve impulse.
(Nerve impulses can affect the rate of heartbeat –sympathetic and parasympathetic nerves but not its intrinsic rate also hormones such as adrenalin can also affect heart rate)

Because the origin actually arises in the heart itself it is referred to as being myogenic rather than for example skeletal muscles, which are neurogenic and require an external nervous impulse to contract.

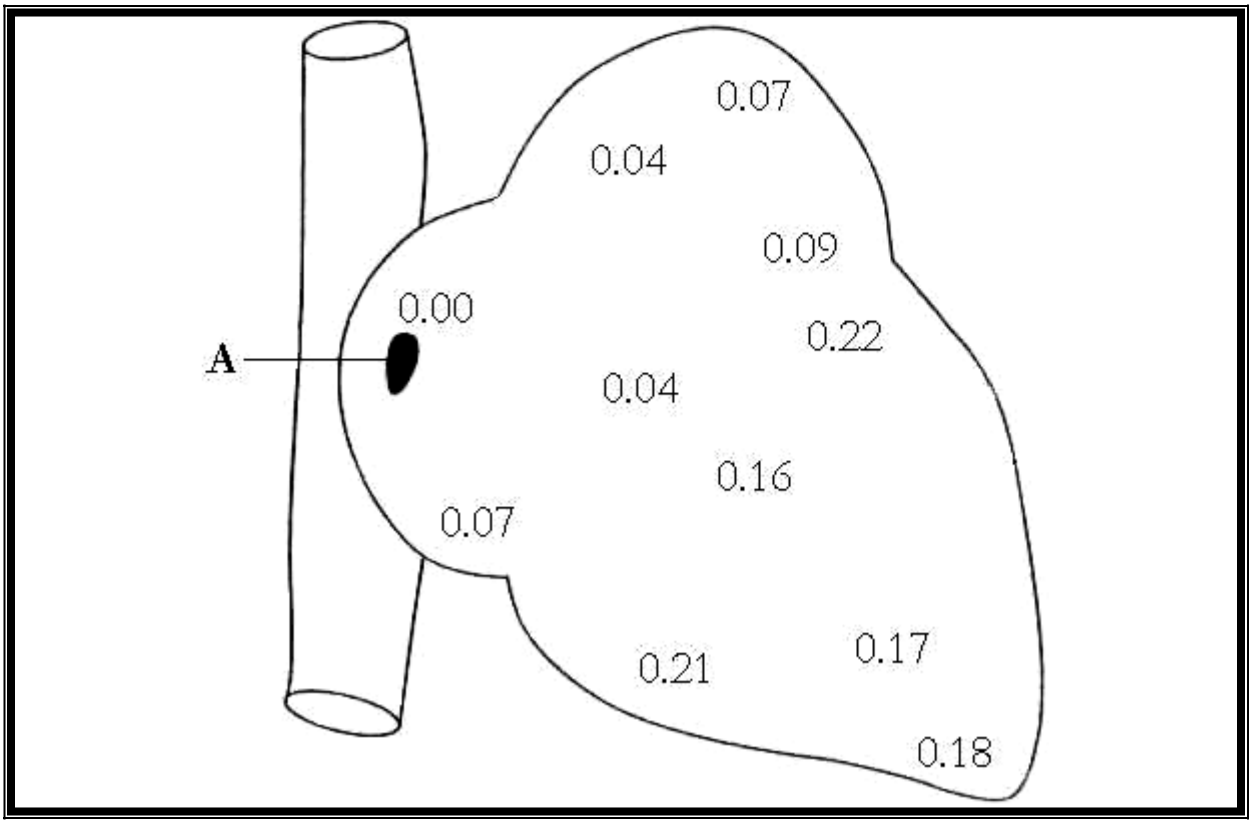
Excitation of heart muscle originates in a small patch of tissue known as the sinoatrial node (SAN) or pacemaker. Excitation spreads across the walls of the atrium from this node causing contraction of the atria – atrial systole.

Excitation is prevented from spreading directly to the ventricles because of a wall of non-conducting tissue. This is important as it means there is a delay between contraction of the atria and the ventricles, so preventing them contracting at the same time.

However, there is a second node located at the base of the atria called the atrio-ventricular node (AVN), this picks up the excitation spreading from the atria and conducts a wave of excitation down long muscle fibres called the Bundle of His as it passes down to the ventricle it branches into Purkinje fibres which carry the wave of excitation from the apex of the ventricles upwards. Contraction of the ventricles starts from the bottom of the ventricles upwards, ventricular systole.



The diagram shows how electrical activity may spread over the surface of the heart during a single heartbeat. The figures represent times, in seconds.



a. Give the name of the structure labeled A.

____

b. Describe the position of this structure in the heart.

____

c. Use the times on the diagram to describe the passage of electrical activity over the surface of the heart.

____

____

____

Electrocardiograms

Like any other muscle, cardiac muscle contracts as a result of electrical stimulation. The cardiac impulse spreads through the heart starting at the pacemaker. The waves of depolarization that spread through the heart during each cardiac cycle generate electrical currents, which in turn spread through the interstitial fluid and on to the body's surface. Recording electrodes placed on the surface of the body on opposite sides of the heart, are used to detect such electrical disturbances. These signals are then transmitted to an electrocardiograph which amplifies and records the electrical activity.

The record, which results from this procedure, is termed an **electrocardiogram** (**ECG**). A typical ECG consists of waves that correspond to particular cardiac events. The P wave is caused by atrial contraction; the QRS wave is caused by ventricular contraction; and the T wave is caused by ventricular relaxation. Heart rate can be calculated from the R-R interval.

Task

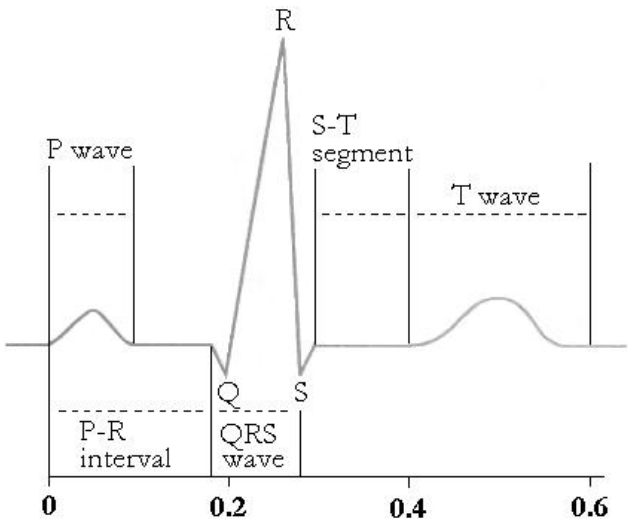
On a copy of the above passage:

1.
    a. Circle in pen the part of the heart where the impulse starts.
    b. Underline in pen the name given to the record of the electrical activity.
    c. Underline in pencil the waves that make up a typical ECG.
    d. Use the information from the passage to annotate the diagram opposite.

2. What was the heart rate of the patient when this ECG trace (Fig.1) was recorded?

3. What was the time taken for:
    a. Conduction of impulse across the atria?
    b. Conduction of impulse over the ventricles?
    c. Period of relaxation of the ventricular muscle?
    d. Delay between ventricular relaxation and atrial contraction?

    Explain your answers.

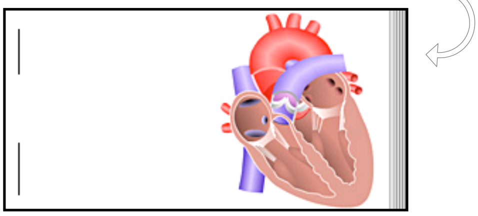


Putting it all together

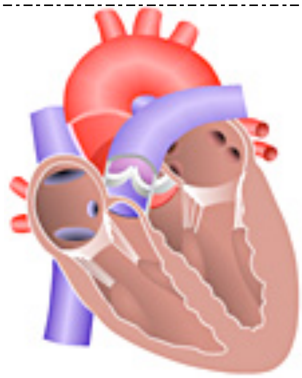
Cardiac Cycle Flip Book

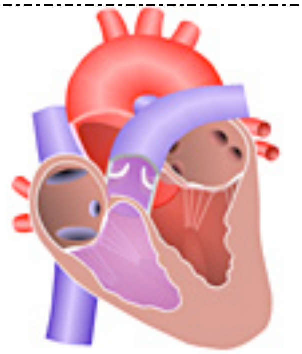
Make your own cardiac cycle animation with the cards below.

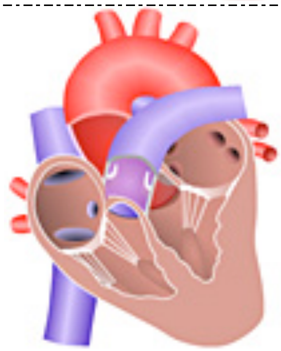
1. Cut out each of the rectangles.
2. Arrange in the correct order. Look at which region of the heart is contracted and look at the valves to help you.
3. Choose a sensible start point for the cycle and place that card on the top, with the rest in the correct order below.
4. Try and create a staggered edge so that it is easier to flip your book:

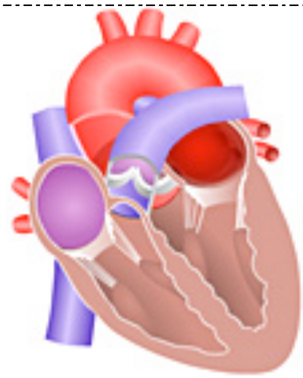


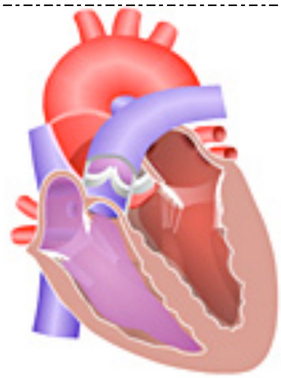
5. Staple on the left hand side.
6. Write some notes on each card to explain what's happening in the picture. Include pressure and volume changes as well as electrical signals.

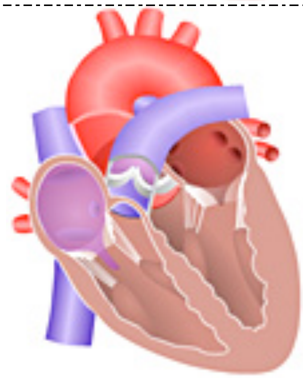


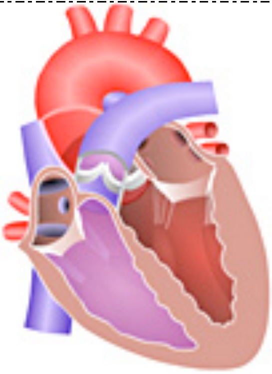


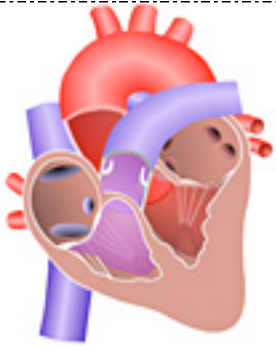


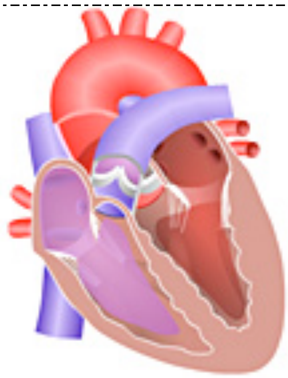


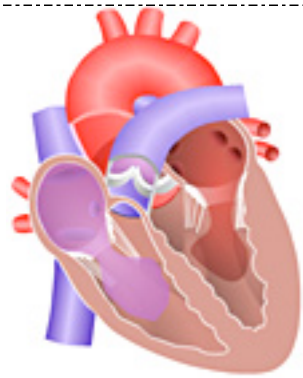


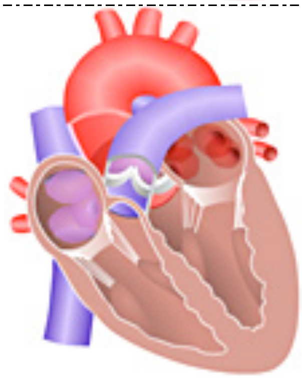


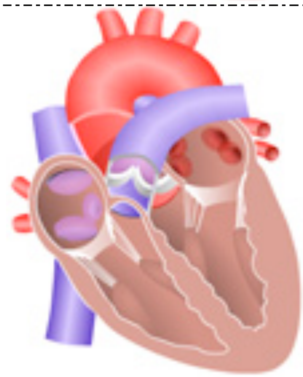










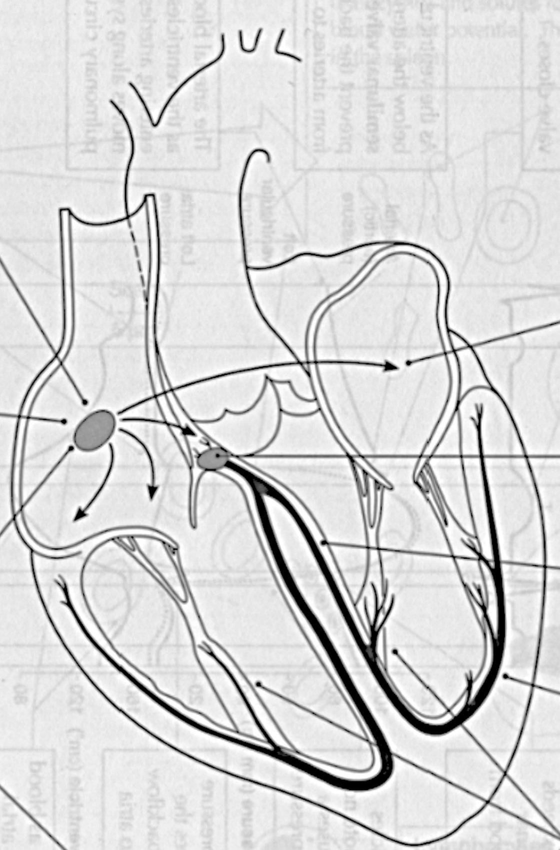


Control of the heartbeat

Autonomic neurones may alter the time it takes to complete a single cycle (heartbeat). A branch of the **vagus** (**parasympathetic**) nerve *decreases* the rate of discharge from the S-A node, whilst the **cardiac/accelerator (sympathetic) nerve** *increases* the rate of the discharge from both S-A and A-V nodes. A typical resting heart rate of 70 b.p.m. indicates that vagal activity dominates – the heart shows **vagal tone**.

Hormones such as thyroxine and adrenaline may increase the rate of discharge from the S-A node.
Drugs such as **beta-blockers** prevent the binding of adrenaline to **ß-receptors** and so may be prescribed to control heartbeat during times of stress, e.g. examinations.

Sino-atrial node: like all nodal cells the cells of this area of the myocardium of the right atrium are **self-excitable (myogenic)** – they may spontaneously and rhythmically generate action potentials *within themselves*. The membranes of cells of the S-A node are especially permeable to Na^+ ions, and are more easily depolarised – this depolarisation is triggered by extension of these cells as blood returns to the heart from the systemic circulation through the venae cavae. The cells of the S-A node have an inherent rate of depolarisation and repolarisation of about 78 cycles per minute which is faster than any other cells in the myocardium. The S-A node thus generates impulses which spread to other areas of the conduction system and myocardium so frequently that they are not able to generate impulses at their own inherent rate. In this way the sino-atrial node acts as the '**pacemaker**' for the rhythmical contraction of the heart.



Cardiac output
The volume of blood expelled from the left ventricle per minute

= **stroke volume** (volume expelled with each 'beat') × **heart rate** (number of beats per minute)

So cardiac output can be changed e.g. during exercise by adjusting both heart rate (most common) and stroke volume (slightly more difficult).

A wave of excitation spreads from the S-A node across the two atria causing them to contract simultaneously and depolarising the atrio-ventricular node.

The atrio-ventricular node slightly delays the wave of depolarisation since a greater depolarisation is necessary to cause contraction of the more massive ventricles.

The atrio-ventricular bundle (bundle of His) runs through the cardiac skeleton and transmits the wave of depolarisation through the interventricular septum down towards the apex of the heart.

Purkyne fibres are the actual conducting fibres which distribute the action potential throughout the myocardium. Squeezing of blood starts from the apex (base) of the heart.

Papillary muscles are excited by the wave of depolarisation – as they contract they tauten the chordae tendineae to prevent blow back of blood to the atria as ventricular contraction continues.

Summary The rhythmic beating of the heart is under both **internal** (**intrinsic**) control due to the self-excitability of the S-A node and **external** (**extrinsic**) control by both autonomic neurones and hormones.

Blood vessels transport blood to tissues and organs:

this is a **mass flow system** depending on **pressure generated by contraction of the ventricles.**

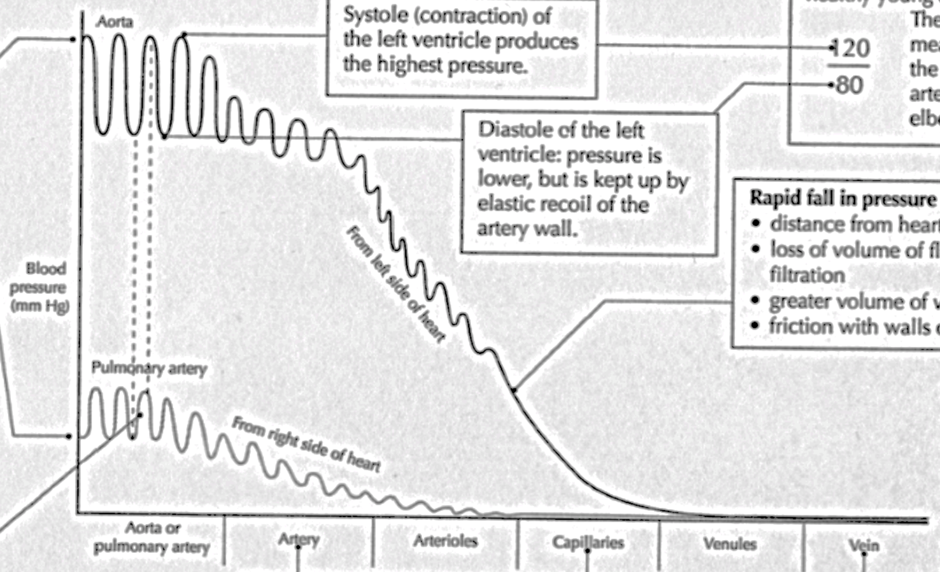
There is a higher pressure in the aorta because the muscular wall of the left ventricle is thicker than the wall of the right ventricle: contraction is therefore more powerful in the left ventricle.

Systole (contraction) of the left ventricle produces the highest pressure.

Normal values in a healthy young adult are: $\frac{120}{80}$ These are measured in the brachial artery at the elbow.

Diastole of the left ventricle: pressure is lower, but is kept up by elastic recoil of the artery wall.

Rapid fall in pressure in capillaries:
- distance from heart
- loss of volume of fluid due to filtration
- greater volume of vessels
- friction with walls of vessels.



Both sides of the heart contract together, so the **pattern** of contraction (systole) and relaxation (diastole) is identical.

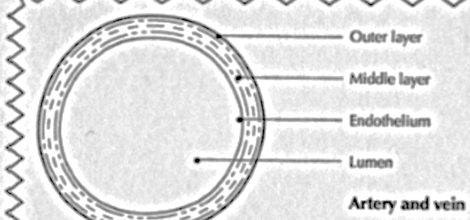
Hypertension (high blood pressure) is the most common circulatory disease. Normal blood pressure is $^{120}/_{80}$ – any value above $^{140}/_{90}$ indicates hypertension and $^{160}/_{95}$ is considered dangerous. Uncontrolled hypertension may damage heart (heart enlarges and demands more oxygen), brain (CVA, or stroke, which ruptures cerebral arteries supplying brain) and kidneys (glomerular arterioles are narrowed and deliver less blood). Treatment includes weight reduction in obese patients, restriction of Na^+ intake, increased Ca^{2-}/K^+ intake and stopping smoking. Vasolilators, beta-blockers and diuretics are widely prescribed.

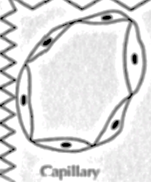
Varicose veins are so dilated that the valves do not close to prevent backflow of blood. The veins lose their elasticity and become congested. Predisposing factors include age, heredity, obesity, gravity and compression by adjacent structures. Common sites are the legs (where poor circulation may lead to haemorrhage or ulceration of poorly-nourished skin), the rectal-anal junction (haemorrhoids may bleed and cause mild anaemia), the oesophagus (caused by liver cirrhosis or right-sided heart failure – may lead to haemorrhage and death) and the spermatic cord (may reduce spermatogenesis).

Structure and function of blood vessels

Outer layer of collagen fibres	Yes	No	Yes
Middle layer of elastic fibres and fibres of smooth muscle	Thick	Absent	Thin
Inner layer: endothelium of pavement epithelium	Yes	Yes	Yes
Valves	No	No	Yes
	Transport of blood at high pressure, from heart to organs: strong and elastic to resist pressure changes	Exchange of materials between blood and tissue fluid	Return of blood at low pressure from organs to heart

These pressure changes can be felt as a **pulse** anywhere that an artery can be pressed against a bone (hard surface)
Most commonly:
- **radial pulse** – artery over end of radius at the wrist;
- **temporal pulse** – artery over temporal bone of skull (just in front of the earlobe).





- Thin walls so short diffusion distance.
- Enormous surface area so more particles in a set amount of time.
- There may be pores between cells of endothelium.

Blood flow through the heart is controlled by two phenomena: the opening and closing of the valves and the contraction and relaxation of the myocardium. Both activities occur without direct stimulation from the nervous system; the valves are controlled by the pressure changes in each heart chamber, and the contraction of the cardiac muscle is stimulated by its conduction system.

Inpulse transmission through the heart's conduction system generates electrical currents which can be recorded using an electrocardiograph and presented as an **electrocardiogram** (ECG).

The QRS wave (complex) represents **ventricular depolarisation** and is strong enough to mask atrial repolarisation.

The P wave indicates **atrial depolarisation** – the spread of an impulse from the SA node through the two atria. It is less powerful than the QRS complex since the atria are less massive than the ventricles.

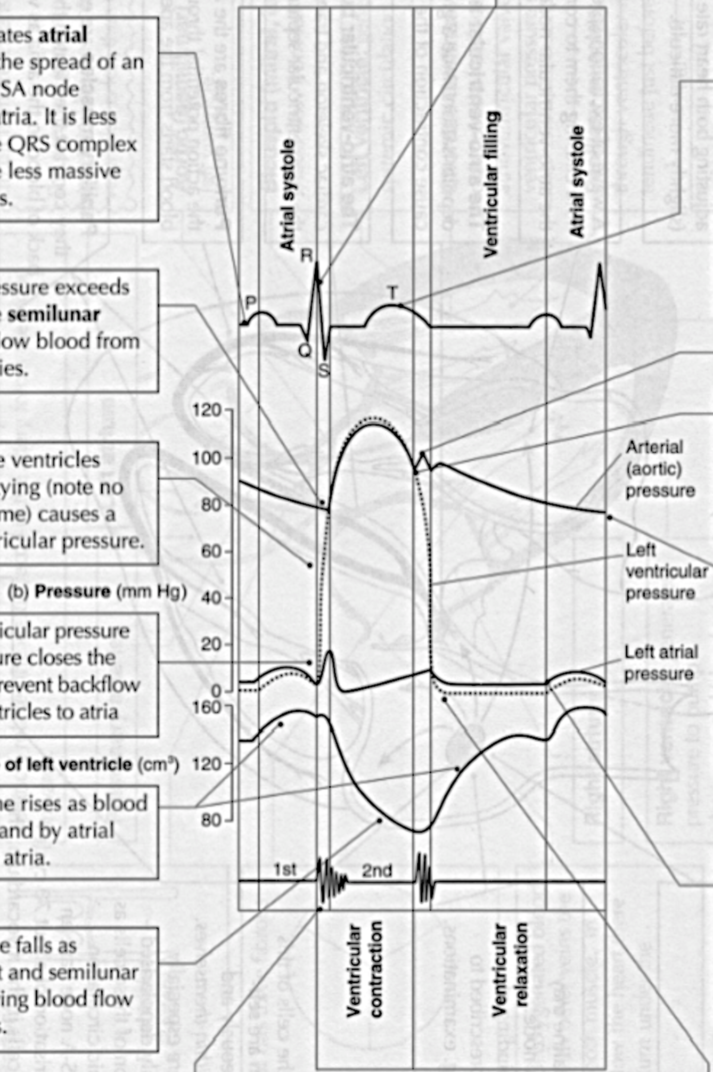
The T wave represents **ventricular repolarisation**.

The dicrotic notch is the slight increase in pressure due to recoil of the arteries as the semilunar valve closes.

As ventricular pressure exceeds atrial pressure the **semilunar values** open to allow blood from ventricles to arteries.

Contraction of the ventricles without any emptying (note no reduction in volume) causes a sharp rise in ventricular pressure.

As the ventricular pressure falls below the arterial pressure the **semilunar valves** snap shut to prevent the backflow of blood from arteries to ventricle.



Sharp rise in ventricular pressure above atrial pressure closes the **cuspid valves** to prevent backflow of blood from ventricles to atria

The arterial blood pressure falls as the ventricles relax (no blood entering arteries) and blood moves along systemic and pulmonary circuits.

Ventricular volume rises as blood moves (passively and by atrial contraction) from atria.

About 70% of blood flows passively from atria to ventricles but this increase in pressure during atrial systole is necessary to force the remaining 30% through to the ventricles.

Ventricular volume falls as ventricles contract and semilunar valves open allowing blood flow through to arteries.

Heart sounds are caused by turbulence in blood flow created by closure of the valves. The first sound ("lubb") is caused by the closure of the cuspid (atrioventricular) valves soon after ventricular systole begins, the second sound ("dupp") is created by the closure of the semilunar valves towards the end of ventricular systole. The pause between the second sound and the first sound of the next cycle is about twice as long as the pause between the first and second sound of each cycle. Thus the cardiac cycle can be heard as "lubb, dupp, pause; lubb, dupp, pause; lubb, dupp, pause".

As the atrial pressure rises due to atrial filling, the ventricular pressure falls as the ventricular muscle relaxes. As the ventricular pressure falls below the artial pressure the **cuspid valves** open allowing blood to flow (initially passively) from atria to ventricles.

Blood flows from an area of higher pressure to one of lower pressure. The diagram relates pressure changes to heartbeat in the left side of the heart – the same pattern exists in the right side although pressures are somewhat lower there.